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(54) Title: DETERMINING A PARAMETER OF A COMPONENT IN A COMPOSITION

(57) Abstract

A method of determining a parameter selected from the electrical conductivity and the volume fraction of a component in a composition comprising a plurality of components is provided. The method comprises measuring the electrical conductivity of the composition, and selecting a relationship between the conductivity of the composition and a plurality of composition parameters including, for each component, physical parameters representing the conductivity and the volume fraction of the component, said relationship being such that the components are substantially equally represented in said relationship by means of said physical parameters. The selected parameter of the component in the composition is determined from said relationship and the measured conductivity of the composition.

DETERMINING A PARAMETER OF A
COMPONENT IN A COMPOSITION

The present invention relates to a method of
determining a parameter selected from the electrical
conductivity and the volume fraction of a component in a
composition comprising a plurality of components. The
5   invention is of particular interest for determining the
volume fraction of a component of an earth formation, for
example to determine the hydrocarbon-content of a
hydrocarbon bearing earth formation. Various known
methods of determining such content have been applied
10   until now, which known methods are generally based on
empirical models.

One such known method is described in "Electrical
conductivities in oil-bearing shaly sands", Waxman M.H.
and Smits L.J.M., SPE paper 1863-A presented at 42nd Ann.
15   Fall Meeting, Houston, October 1-4, 1967.

This publication discloses a method of determining a
parameter selected from the electrical conductivity and
the volume fraction of a component in a composition
comprising a plurality of components, wherein the
20   electrical conductivity of the composition is measured,
and a relationship between the conductivity of the
composition and the conductivity of a component is
selected.

This known method uses the following relationship
25   which is generally referred to as the Waxman-Smits model:

$$C_O = C_W \ / \ F^* + BQ_V \ / \ F^*$$

where C_O = conductivity of fully brine saturated rock
      C_W = conductivity of brine present in the formation

F^* = a formation factor

B = equivalent conductance of sodium clay-exchange cations as a function of C_w

Q_v = cation exchange capacity per unit pore volume.

5   The results achieved with this known method are not always sufficiently accurate, probably because of the empirical nature of the Waxman-Smits model which provides a relationship between the earth conductivity and the various other parameters.

10   It is an object of the invention to provide a more accurate method of determining a parameter selected from the electrical conductivity and the volume fraction of a component in a composition comprising a plurality of components.

15   The method according to the invention thereto comprises:

-      measuring the electrical conductivity of the composition;

-      selecting a relationship between the electrical

20   conductivity of the composition and a plurality of composition parameters including, for each component, physical parameters representing the electrical conductivity and the volume fraction of the component, the components being substantially equally represented in

25   said relationship by means of said physical parameters; and

-      determining said selected parameter from said relationship and the measured conductivity of the composition.

30   It is to be understood that by the electrical conductivity is meant the electrical conductivity itself or any quantity derived therefrom, such as the electrical resistivity. Furthermore, the feature that the components are substantially equally represented in the relationship

35   implies that each component is represented in the

relationship in substantially the same way as any other
of the components.

With the method according to the invention it is
achieved that results of increased accuracy are provided.
The selected relationship takes accurately account of the
individual contributions of the components to the
conductivity of the composition. The relationship applied
in the method according to the invention is symmetrical
in the components, i.e. no component is favoured over
another component. Moreover, it was found that the method
according to the invention provides the desired accuracy
for any percolation threshold of the components. In this
respect it is to be understood that the amount of
percolation of a component refers to the degree of
continuity of the component in the composition. For
example, vanishing percolation of a component implies
that the component is fully dispersed in the composition,
and full percolation of a component implies that the
component is continuous throughout the composition.

Advantageously said plurality of composition
parameters includes at least one fitting parameter, and
wherein each fitting parameter is determined by applying
said relationship to a data set obtained by measuring the
electrical conductivity of at least one sample
representative for said composition for various
magnitudes of at least one of said parameters.

Preferably said plurality of parameters includes an
auxiliary parameter depending on the geometrical
configuration of the components in the composition.

Accurate geometrical representation by the auxiliary
component is achieved if said auxiliary parameter is
selected so as to be a function of a plurality of
variables, each variable depending on the conductivity of
one of said components and a mixing coefficient, whereby

the mixing coefficients depend on the geometrical
configuration of the components in the composition.

Advantageously the step of determining each fitting
parameter by applying said relationship to the data set
5   of the component is carried out through an iterative
process. Suitably the iterative process includes
repeatedly applying said relationship in a minimisation
scheme. The minimisation scheme is preferably applied to
an incoherence between the measured electrical
10   conductivities of said components and the electrical
conductivities of the components as determined through
said relationship.

The invention will be described hereinafter in more
detail and by way of the following example and
15   comparative example.

Example

Consider an isotropic system with essential spherical
inclusions in the form of an earth formation which
essentially consists of four components: non-conducting
20   porous rock matrix, non-conducting hydrocarbon fluid,
conducting clay, and conducting brine. The conductivity
of the formation depends on the fractional brine
saturation of the pore space, and the hydrocarbon fluid
component is grouped with the rock matrix, both being
25   non-conducting. Thus, the hydrocarbon component and the
rock matrix component only enter the equations with the
sum of their volume fractions. The effective conductivity
σ_{eff} of this earth formation is evaluated through the
expression

$$(\sigma_{eff} - \sigma_0) \cdot (L\sigma_{eff} + (1-L)\sigma_0)^{-1} = \sum \phi_k (\sigma_k - \sigma_0) \cdot (L\sigma_k + (1-L)\sigma_0)^{-1}$$

30   wherein σ_0 represents the auxiliary parameter in the
form of a conductivity tensor

$k = 1 \ldots N$, N being the number of components

σ_{eff} represents the conductivity tensor of the sample

σ_k represents the conductivity tensor of component k

ϕ_k represents the volume fraction of component k

L represents the depolarisation tensor (shape tensor)

Preferably the depolarisation tensor is positive and has unit trace. In an attractive embodiment the depolarisation tensor equals 1/3 times the unit tensor.

The term σ_0 denotes an auxiliary parameter which can be thought of as being an additional host medium into which components are added until the host medium has been completely replaced by the components so that no volume fraction is associated with the host medium. The existence of the host medium enables the model to be symmetrical in all its constituents: none of the components rock, clay or brine in the model is favoured over any of the other components. The dependence of σ_0 on various parameters, yet to be determined, governs the percolation behaviour of the model. Setting $\sigma_0 = \sigma_{brine}$ leads to the known Average T-matrix Approximation, also referred to as the generalised Clausius-Mossotti equation. This model has a clear asymmetry between the brine component and the other components since only the brine component will percolate, irrespective of its volume fraction. Selecting a self-consistent host medium conductivity, $\sigma_0 = \sigma_{eff}$, leads to the known Coherent Potential Approximation, also referred to as the generalised Bruggeman equation. This model is symmetrical in all components but has the drawback of requiring unrealistically high percolation thresholds for each component.

In a suitable embodiment, the auxiliary parameter σ_0 is selected as follows:

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$$\sigma_0 = \Sigma \ h_k \ \sigma_k \ ; \ \text{for} \ \ k = 1, \ 2, \ 3$$

wherein h_k represents the mixing coefficient tensor
pertaining to component k, which tensor contains mixing
coefficients representing geometrical information on the
spatial distribution of the components in the formation.
These coefficients determine the connectivity, i.e. the
amount of percolation of the individual components. The
coefficients are non-negative and fulfil the
normalisation condition:

$$\Sigma \ h_k = 1; \ \text{for} \ k = 1, \ 2, \ 3$$

The normalisation relation ensures that the resulting
effective conductivity σ_{eff} satisfies the Hashin –
Shtrikman bounds, which are well known to those skilled
in the art.
Furthermore, a component with a vanishingly small volume
fraction can not percolate, hence the corresponding
connectivity parameter should vanish:

$$\lim h_k = 0; \ \text{for} \ \phi_k \Rightarrow 0$$

Suitably the mixing coefficient tensor is selected to
be

$$h_k = \lambda_k \phi_k{}^{v}{}_k \ (\ \Sigma \lambda_n \phi_n{}^{v}{}_n)^{-1}$$

wherein $k, n = 1 \ ... \ N$, N being the number of
components in said plurality of components

λ_k represents the percolation rate tensor pertaining
to component k

ϕ_k represents the volume fraction of component k

v represents the percolation exponent pertaining to
component k

Suitably at least one of h_k, λ_k and v forms a fitting parameter.

A data set on 27 shaly-sand core samples has been used to test the invention, which data set is described
5 in the above indicated SPE paper. This publication provides C_o - C_w curves on the core samples ranging from almost clean sand (Q_v = 0.017 eq/l) to extremely shaly sand (Q_v = 1.47 eq/l). The samples contained Kaolinite, Montmorillonite and Illite, either in combination or
10 separately in each sample. The characteristic petrophysical data of each sample are listed in the appended Table, in which ϕ denotes the porosity of the sample, κ denotes the permeability of the sample, and Q_v denotes the cation exchange capacity per unit pore volume
15 of the sample. The conductivity of each sample in fully brine saturated condition was measured for eight to ten salinities of the brine. Furthermore, concentration membrane potential measurements were made of the samples.

The parameters in this model were selected as
20 follows:

1) Brine;

The volume fraction of brine, ϕ_b, is determined by the porosity, the amount of clay-bound water, and the water saturation S_w. The brine conductivity σ_b (=C_w) is
25 determined by the brine salinity and the brine temperature. The two percolation parameters, λ_b and v, are free parameters.

2) Rock / Hydrocarbon;

The volume of hydrocarbons, ϕ_{hc}, is determined by the
30 total porosity, the amount of clay-bound water, and the hydrocarbon saturation $1-S_w$, while the volume of the rock matrix, ϕ_r, is calculated using the sum rule and the volume fractions. Both the rock and the hydrocarbon have vanishing conductivity. The percolation parameters λ_r and
35 λ_{hc} of both components was set at value 1. The mixing

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coefficient pertaining to rock/hydrocarbon $h_{r/hc}$ follows
from the condition $\sum h_k = 1$.

3) Clay;

The volume of clay ϕ_C and the clay conductivity σ_C are
free fitting parameters. The percolation rate λ_C was set
at a value 0, which is a suitable choice for non-
laminated clays. It furthermore appeared that an
additional free parameter did not give a significant
improvement of the model fit to the data set.

The C_O – C_w measurements were made for an extreme
salinity range, namely a brine salinity between 1 – 300
g/l. For a given sample the brine volume fraction varied
only slightly over the whole salinity range. In view
thereof the percolation parameter v was set equal to
unity in the test, thereby reducing the percolation
parameter h_b to a constant, and reducing the number of
free parameters to three.

For each sample, a fit to the C_O – C_w curve was made
by minimising the relative incoherence defined as:

$$\sum \Delta^2 \, C_O - C_w = \sum_{\text{salinities}} \left(\frac{C_{O,\text{calc}} - C_{O,\text{meas}}}{C_{O,\text{meas}}} \right)^2$$

wherein

$C_{O,\text{calc}}$ = the calculated conductivity of the fully brine
saturated rock samples;

$C_{O,\text{meas}}$ = the measured conductivity of the fully brine
saturated rock samples;

$\sum$ = summation over the salinities.

The results for the three fitting parameters ϕ_C, σ_C
and h_b, and the relative incoherence are given in the
appended Table.

Furthermore, the Table gives the incoherence between the membrane potential (ψ_{calc}) determined by the method of the invention and the measured membrane potential (ψ meas):

$$\sum \Delta^2_{MP} = \sum_{salinities} \left(\frac{\psi_{calc} - \psi_{meas}}{\psi_{meas}} \right)^2$$

The membrane potential is a particularly interesting quantity for being a direct, non-destructive, measure of the clay contribution to the overall conductivity, which has not been used to determine the fitting parameters.

To illustrate the invention more specifically, reference is made to the following comparative example.

Comparative example

As stated above Ref. 1 discloses, apart from the data set on the 27 core samples, furthermore an empirical model which is generally referred to as the Waxman-Smits model. To compare the method according to the invention with the Waxman-Smits model, the relative incoherence between the measured conductivities and the conductivities found from the Waxman-Smits model, and the relative incoherence between the measured concentration membrane potentials and the concentration membrane potentials found from the Waxman-Smits model, were determined. These relative incoherences for all 27 samples are listed in the Table. In applying the Waxman-Smits model, use has been made of the well known expression:

$$C_O = C_W / F^* + BQ_V / F^*$$
$$\text{with } F^* = \phi^{-m}$$

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where m is a free parameter (also referred to as the
cementation exponent), Q_V is determined from sample
measurements, just as the porosity ϕ, and the standard B-
chart has been used to calculate the salinity and
5   temperature effects on the conductivity measurements.

From a comparison between the incoherence values
found by using the method according to the invention, and
the incoherence values found by using the Waxman-Smits
model, it is clear that the method according to the
10   invention provides improved results. Especially the
extremely low incoherence values for the concentration
membrane potential, which values are moreover fairly
constant over the entire Q_V range, indicates that the
method according to the invention provides results of
15   increased accuracy.

The method according to the invention can suitably be
applied to determine the volume fraction of brine or
hydrocarbon in an earth formation, whereby a well-log
representing the electrical conductivity of the formation
20   is provided. Such application can, for example, be
carried out in the following manner. The well-log of the
electrical conductivity of the earth formation is made
using a logging tool lowered in a borehole formed in the
earth formation. For an isotropic formation with
25   components brine (subscript B), clay (subscript C), and
non-conducting rock + hydrocarbon (subscript R/HC) the
rock and the hydrocarbon are grouped together because of
their vanishing conductivities. The selected relationship
then is:

$$\frac{\sigma_{eff} - \sigma_o}{\sigma_{eff} + 2\sigma_o} = \sum_{k=1}^{3} \phi_k \cdot \frac{\sigma_k - \sigma_o}{\sigma_k + 2\sigma_o}$$

30   wherein

$$\sigma_0 = \sum h_k \sigma_k$$
$$h_k = \lambda_k \phi_k{}^{v_k} \left(\sum \lambda_n \phi_n{}^{v_n} \right)^{-1}$$

in which

σ_0 represents the auxiliary parameter

$k,$ $n = 1 \ldots N$, N being the number components

σ_{eff} represents the conductivity of the earth formation

5   σ_k represents the conductivity of component k

ϕ_k represents the volume fraction of component k

h_k represents the mixing coefficient pertaining to
        component k;

λ_k represents the percolation coefficient pertaining to
10   component k

$v_{k,n}$ represents the percolation exponent pertaining to
        component k, n

Each component k has four parameters: ϕ_k, σ_k, λ_k, and
v_k, of which ϕ_B, σ_B and $\sigma_{R/HC}$ are directly measured.
15   Furthermore, $\lambda_C = 0$ for dispersed clay. From the sum
rules $h_{R/HC}$ and $\phi_{R/HC}$ follow. Parameters which are yet to
be determined are σ_C, λ_B, v_B and ϕ_C. These parameters are
determined through forward modelling on experimental
data. σ_C, λ_B and v_B are invariable over the geological
20   formation , while ϕ_B will be depth dependent. The
experimental data for the parameter determination consist
of well-log measurements from a brine containing zone,
laboratory Formation Resistivity Factor (FRF)
measurements and brine saturation experiments. The log
25   information from the brine containing zone is used to
correlate the local parameter ϕ_C to suitable logs/log
combinations, as is known to those skilled in the art of
well logging. σ_C, λ_B and ϕ_B and the correlation of φ_C to
suitable logs/log combinations can be used in hydrocarbon
30   bearing formations. From the well-log, the above
relationship and the indicated parameters, the volume

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faction of brine and thus also the volume fraction of
hydrocarbon is determined as a function of depth.

sample No.	petrophysical data			parameters			incoherence for present invention		incoherence for prior art	
	ϕ	κ [mD]	Q_ν [eq/l]	φ_c	σ_c [mS/cm]	h_B	$\sum \Delta^2_{c_0-c_w}$	$\sum \Delta^2_\psi$	$\sum \Delta^2_{c_0-c_w}$	$\sum \Delta^2_\psi$
1	0.239	659	0.017	0.0532	2.9581	0.2016	0.002	0.018	0.009	0.026
2	0.212	105	0.052	0.1822	1.3537	0.2038	0.002	0.035	0.061	0.099
3	0.231	397	0.052	0.1376	1.8607	0.2517	0.002	0.014	0.031	0.097
4	0.080	1.34	0.26	0.1323	1.3325	0.1788	0.010	0.119	0.045	0.010
5	0.154	55	0.2	0.3216	1.4851	0.3752	0.005	0.042	0.149	0.128
6	0.215	29	0.095	0.3467	1.0193	0.1370	0.003	0.026	0.206	0.257
7	0.171	3.5	0.053	0.3779	0.7847	0.1200	0.008	0.016	0.312	0.446
8	0.171	7.66	0.053	0.3119	0.8994	0.1274	0.007	0.018	0.234	0.366
9	0.199	57	0.085	0.3935	1.0627	0.1613	0.007	0.025	0.276	0.351
10	0.125	0.042	0.253	0.432	0.3113	0.0255	0.029	0.074	0.483	0.262
11	0.125	0.0106	0.253	0.4007	0.2590	0.0233	0.037	0.057	0.348	0.203
12	0.110	1.86	0.28	0.5855	0.8601	0.1326	0.018	0.010	0.760	0.542
13	0.110	0.3	0.28	0.5998	1.0802	0.1286	0.020	0.016	0.868	0.589
14	0.110	2.08	0.28	0.5815	1.4104	0.1998	0.054	0.029	0.854	0.539
15	0.092	0.128	0.41	0.509	0.6025	0.0402	0.027	0.025	0.917	0.449
16	0.103	0.024	0.67	0.7202	1.4537	0.1103	0.010	0.013	1.263	0.529
17	0.140	0.575	0.33	0.7763	1.5783	0.0977	0.050	0.013	1.606	0.919
18	0.259	3.78	0.59	0.7033	2.8964	0.1357	0.012	0.007	1.173	0.507
19	0.259	17.1	0.59	0.6408	2.8227	0.1484	0.010	0.012	0.823	0.376

sample No.	petrophysical data			parameters			incoherence for present invention		incoherence for prior art	
	ϕ	κ [mD]	Q_ν [eq/l]	φ_c	σ_c [mS/cm]	h_B	$\sum \Delta^2_{c_0-c_w}$	$\sum \Delta^2_\psi$	$\sum \Delta^2_{c_0-c_w}$	$\sum \Delta^2_\psi$
20	0.259	44.8	0.59	0.5978	3.4771	0.2113	0.003	0.023	0.674	0.286
21	0.238	315	0.29	0.6984	1.3859	0.1812	0.009	0.031	0.632	0.546
22	0.225	1.92	0.72	0.7651	2.4172	0.0766	0.016	0.013	1.808	0.637
23	0.242	54.3	1.04	0.7306	4.0758	0.1165	0.022	0.011	1.640	0.490
24	0.216	0.546	0.81	0.7751	2.6418	0.0659	0.021	0.014	2.103	0.703
25	0.187	0.0348	1.27	0.7995	3.4510	0.0726	0.005	0.040	0.490	0.369
26	0.229	1.53	1.47	0.7491	5.0425	0.0887	0.042	0.026	2.155	0.470
27	0.209	0.263	1.48	0.7656	5.1455	0.0884	0.001	0.067	0.495	0.326

TABLE

C L A I M S

1.   A method of determining a parameter selected from the
electrical conductivity and the volume fraction of a
component in a composition comprising a plurality of
components, the method comprising:

5   -   measuring the electrical conductivity of the
composition;

-    selecting a relationship between the electrical
conductivity of the composition and a plurality of
composition parameters including, for each component,

10   physical parameters representing the electrical
conductivity and the volume fraction of the component,
the components being substantially equally represented in
said relationship by means of said physical parameters;
and

15   -   determining said selected parameter from said
relationship and the measured conductivity of the
composition.

2.   The method of claim 1, wherein said plurality of
composition parameters includes at least one fitting

20   parameter, and wherein each fitting parameter is
determined by applying said relationship to a data set
obtained by measuring the electrical conductivity of at
least one sample representative for said composition for
various magnitudes of at least one of said parameters.

25   3.   The method of claim 1 or 2, wherein said plurality of
parameters includes an auxiliary parameter depending on
the geometrical configuration of the components in the
composition.

4.   The method of claim 3, wherein said relationship is

30   selected to be

$$(\sigma_{eff} - \sigma_0) \cdot (L\sigma_{eff} + (1-L)\sigma_0)^{-1} = \Sigma \, \phi_k \, (\sigma_k - \sigma_0) \cdot (L\sigma_k + (1-L)\sigma_0)^{-1}$$

wherein σ_0 represents the auxiliary parameter in the form of a conductivity tensor

    $k = 1 \ldots N$, N being the number components

    σ_{eff} represents the conductivity tensor of the sample

    σ_k represents the conductivity tensor of component k

    ϕ_k represents the volume fraction of component k

    L   represents a depolarisation tensor

5. The method of claim 3 or 4, wherein said auxiliary parameter is selected so as to be a function of a plurality of variables, each variable depending on the conductivity of one of said components and a mixing coefficient, whereby the mixing coefficients depend on the geometrical configuration of the components in the composition.

6. The method of any of claims 3-5, wherein said auxiliary parameter is selected to be

$$\sigma_0 = \Sigma \, h_k\sigma_k$$

wherein σ_0 represents the auxiliary parameter in the form of a conductivity tensor representative for the conductivity in the three principal directions;

    $k = 1 \ldots N$, N being the number of components;

    σ_k represents the conductivity tensor of component k;

    h_k represents the mixing coefficient tensor pertaining to component k;

7. The method of claim 5 or 6, wherein said mixing coefficients are selected so that the sum of the mixing coefficients substantially equals unity.

8. The method of any of claims 5-7, wherein said mixing coefficients are non-negative.

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9. The method of any of claims 5-8, wherein each mixing coefficient is selected to be a function of at least the volume fraction of the component pertaining to said mixing coefficient.

10. The method of claim 9, wherein said function is a monotonous increasing function in the volume fraction of the component pertaining to the mixing coefficient.

11. The method of claim 9 or 10, wherein said function is selected so that the mixing coefficient vanishes for vanishing volume fraction of the component pertaining to the mixing coefficient.

12. The method of any of claims 5-11, wherein each mixing coefficient is selected as

$$h_k = \lambda_k \phi_k{}^{v_k} \left(\Sigma \lambda_n \phi_n{}^{v_n} \right)^{-1}$$

wherein $k, n = 1 \ldots N$, N being the number components in said plurality of components

λ_k represents a percolation rate tensor pertaining to component k

ϕ_k represents the volume fraction of component k

$v_{k,n}$ represents a percolation exponent pertaining to component k, n

13. The method of claim 12, wherein at least one of h_k, λ_k and v forms a fitting parameter.

14. The method of any of claims 4-13, wherein the depolarisation tensor is positive.

15. The method of any of claims 4-14, wherein the depolarisation tensor has unit trace.

16. The method of any of claims 4-15, wherein the depolarisation tensor equals 1/3 times the unit tensor.

17. The method of any of claims 1-16, wherein the step of determining each fitting parameter by applying said relationship to the data set is carried out through an iterative process.

18. The method of claim 17, wherein the iterative process includes repeatedly applying said relationship in a minimisation scheme.

19. The method of claim 18, wherein the minimisation scheme is applied to a mismatch between the measured electrical conductivities of said components and the electrical conductivities of the components as determined through said relationship.

20. The method of any of claims 1-19, wherein said composition includes an earth formation.

21. The method of claim 20, wherein said earth formation includes at least one of rock, brine, hydrocarbon fluid and clay.

22. The method of claim 21, wherein said parameter which is determined forms the volume fraction of one of the hydrocarbon fluid and the brine.

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G01V3/38   G01N33/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G01V   G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 398 151 (VINEGAR ET AL.) 9 August 1983 see the whole document ---	1,20
A	GEOPHYSICS, vol. 48, no. 9, September 1983, TULSA US, pages 1258-1268, XP002007681 BUSSIAN, A.E.: "Electrical conductance in a porous medium" see the whole document --- -/--	1,20

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

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5 July 1996	0 1. 08. 96

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JOURNAL OF APPLIED PHYSICS, vol. 58, no. 8, October 1985, NEW YORK US, pages 3236-3243, XP002007682 SHECHAO FENG, ET AL.: "Geometrical model of conductive and dielectric properties of partially saturated rocks" see the whole document -----	1,20

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INTERNATIONAL SEARCH REPORT

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		CA-A-	1161901	07-02-84
		FR-A,B	2474709	31-07-81
		GB-A,B	2068563	12-08-81